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ASPECTS REGARDING THE IMPACT SPEED, AIS AND HIC RELATIONSHIP FOR CAR-PEDESTRIAN TRAFFIC ACCIDENTS

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Abstract
The paper is aimed to the area of research and simulation and virtual reality in engineering design in the transport safety. It is mainly a study of the relationship between parameters such as impact speed, AIS and HIC for the front-end car-pedestrian collision.

1. HEAD INJURY EXPLAINED

The human head is a complex system. It consists of three components:

1. The skull with cranial and facial bones;
2. The skin and other soft tissue covering the skull. Which consists of layers known as the SCALP (Skin, Connective Tissue, Aponeurosis (Galea), Loose connective tissue and Periosteum)
3. The contents of the skull. Most notably the brain, but also including the brain's protective membranes (meninges) and numerous blood vessels (see figure below). [2]

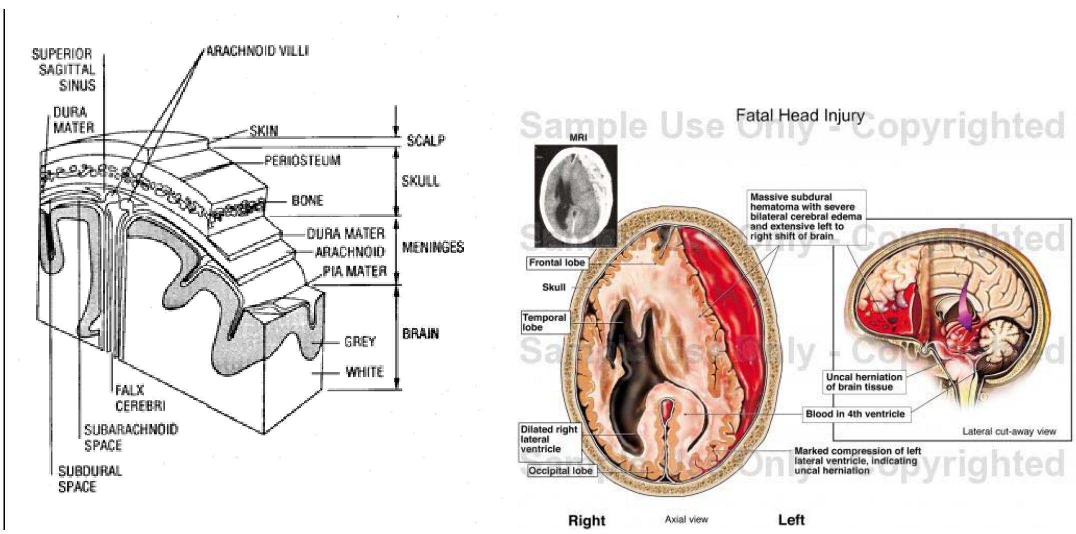

FIG. 1. Head section (left) [2] and fatal head injury with subdural hematoma (right) [4]

Injuries to the skin may be categorized as superficial or deep, and include

- contusion (bruise),
- laceration (cut), and
- abrasion (scrape).

Injuries to the skull may break one or more of the bones of the skull in which case the skull is said to have been fractured (broken). Two aspects of a skull fracture are whether it is open or depressed.

Injuries to the brain and associated soft tissue are the result of either head impact or abrupt head movement (e.g., deceleration injury) or some combination of the two. Injuries may be due to the skull fracturing and being pushed inward (a depressed fracture), or from the brain impacting the interior of the skull, or from internal stressing of the brain (i.e., shear, tension and/or compression). The complexities of the head and brain system are reflected in the rather bewildering array of head injury consequences.

Three various methods are used to categorize brain injuries [2]:
1. The cause of injury, (contact or non-contact);
2. The type of injury, (primary or secondary);
    a. Primary in which the injury occurs at time of initial injury producing event;
    b. Secondary in which the injury results from some injury producing event but does not develop until somewhat later (through an intermediate process such as a metabolic effect);
3. The type of injury, either focal vs diffuse
    a. Focal (i.e. fairly localized)
    b. Diffuse (rather distributed)

In injury producing events, there are generally 3 collisions which occur [2]:
1. The "first collision" is that in which the injury producing event occurs, e.g. the vehicle strikes the pedestrian and as a result the pedestrian is rapidly accelerated and/or rotated.
2. The "second collision" is the movement of the pedestrian and the subsequent contact with the vehicle frontal structure.
3. The "third collision" is when the internal organs of the pedestrian collide and/or move within him.

2. ABREVIATED INJURY SCALE

In order to generally evaluate injuries for any body part, an injury scale has been proposed: AIS (Abreviated Injury Scale). Any injury level is, thus, evaluated on a scale from 1 to 6, as it can be seen in the table below.

The same table describes the relation between AIS and head injury.

Table 1. Abreviated Injury Scale, head injury related [3]

AIS code	Injury level	Fatality probability	Injuries:
1	Minor	0%	Light brain injuries with headache, vertigo, no loss of consciousness, light cervical injuries, whiplash, abrasion, contusion
2	Moderate	0.1-0.4%	Concussion with or without skull fracture, less than 15 minutes unconsciousness, corneal tiny cracks, detachment of retina, face or nose fracture without shifting
3	Serious	0.8-2.1%	Concussion with or without skull fracture, more than 15 minutes unconsciousness without severe neurological damages, closed and shifted or impressed skull fracture without unconsciousness or other injury

			indications in skull, loss of vision, shifted and/or open face bone fracture with antral or orbital implications, cervical fracture without damage of spinal cord
4	Severe	7.9-10.6%	Closed and shifted or impressed skull fracture with severe neurological injuries.
5	Critical	53.1-58.4%	Concussion with or without skull fracture with more than 12 hours unconsciousness with hemorrhage in skull and/or critical neurological indications
6	Survival unsure		death, partly or fully damage of brainstem or upper part of cervical due to pressure or disruption, Fracture and/or wrench of upper part of cervical with injuries of spinal cord

As apparent in table above, the injury severity does not rise linearly with the AIS categories; it rises exponentially. From an AIS equal to three, the severity of injuries rises steeply.

The graphs below show the AIS distribution across level, body parts and velocity

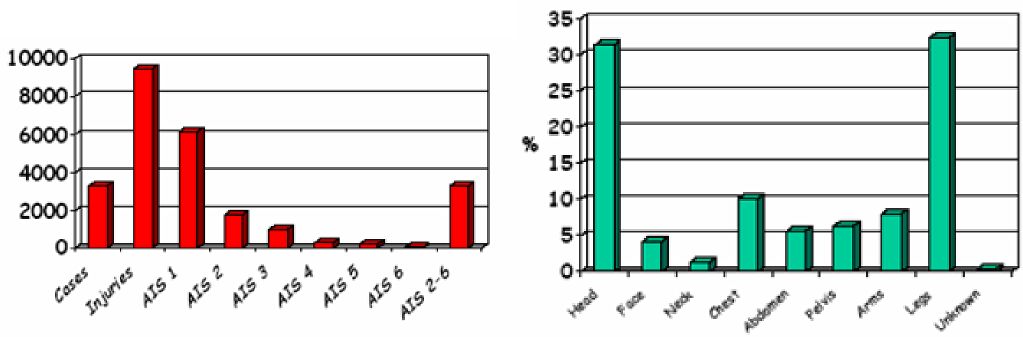

FIG. 2. AIS distribution. AIS degree/nr cases (left) and body regions (right)
[Source: GIDAS Database, Germany]

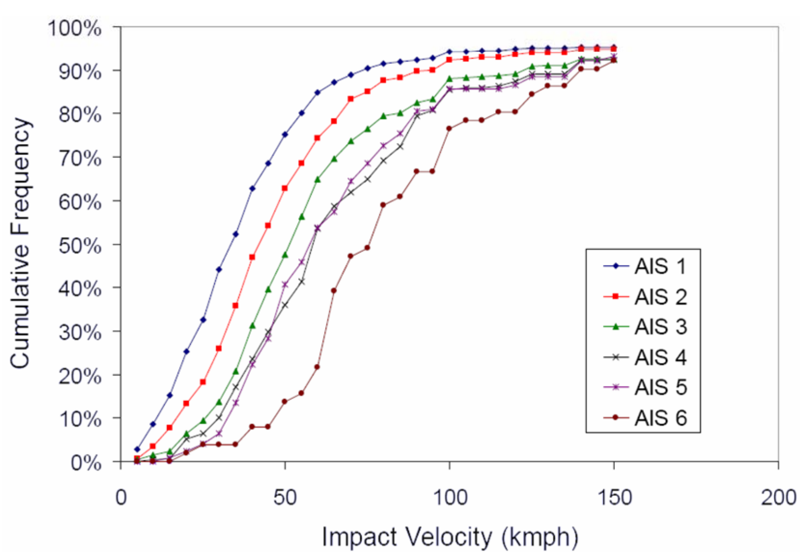

FIG. 3. AIS distribution. Cumulative frequency

Table 2 . AIS – Speed Correlation

Impact speed [km/h]	AIS1+	AIS2+	AIS3+	AIS4+/AIS5+	AIS6+
	[% cumulative]				
5	2.3605	1.2876	0.4292	0.2146	0
10	8.3691	3.2189	1.2876	0.2146	0
15	15.2361	7.7253	2.1459	0.4292	0
20	25.1073	13.3047	6.0086	2.5751	1.7167
25	32.4034	18.0258	9.2275	4.0773	3.8627
30	43.9914	25.9657	13.5193	6.4378	3.4335
35	52.1459	35.8369	20.3863	13.3047	3.8627
40	62.6609	46.9957	31.1159	21.8884	7.5107
45	68.4549	54.0773	39.485	28.1116	7.9399
50	75.1073	62.8755	47.4249	40.7725	13.5193
55	80.2575	68.8841	56.4378	46.1373	15.8798
60	84.9785	74.6781	65.0215	53.6481	21.8884
65	87.3391	78.5408	69.7425	57.7253	39.2704
70	89.0558	83.691	73.6052	64.8069	47.4249
75	90.7725	85.4077	76.3948	68.8841	49.5708
80	91.6309	87.9828	79.6137	72.9614	59.4421
85	92.2747	88.6266	80.2575	75.7511	61.1588
90	92.4893	90.1288	82.618	80.9013	66.7382
95	93.133	90.3433	83.4764	81.3305	66.9528
100	94.6352	92.7039	88.1974	85.8369	76.824
105	94.6352	92.9185	88.412	86.0515	78.7554
110	94.8498	93.3476	88.412	86.0515	78.7554
115	94.6352	93.3476	88.8412	86.0515	80.6867
120	95.279	93.9914	89.2704	87.1245	80.6867
125	95.4936	94.4206	90.9871	88.6266	84.7639
130	95.279	94.4206	91.2017	89.0558	86.6953
135	95.279	94.4206	91.2017	88.8412	86.6953
140	95.7082	95.0644	93.133	92.0601	90.3433
145	95.7082	95.279	92.9185	92.2747	90.5579
150	95.4936	95.279	93.9914	92.9185	92.4893

3. HEAD INJURY CRITERION

The Head Injury Criterion (HIC) has been developed to measure the accelerations acting on the head of occupants, computed with the following equation:

$$HIC = \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a(t)dt \right]^{2.5} (t_2 - t_1) \qquad (1.1)$$

Where
a is a resultant head acceleration
t2-t1 ≤36 ms, t2, t1 selected so as to maximize HIC

This index is used with head-on impacts. A HIC greater than 1000 is basically declared as the threshold value from which high occupant injuries are expected [2].

Recent research by NHTSA related to Improved Injury Criteria have included reviewing the existing regulations which specify a HIC for the 50th percentile male ATD. As of 2000, the NHTSA final rule adopts limits which reduce the maximum time for calculating the HIC to 15 milliseconds (HIC15) vs. the prior HIC36 and revising the limits for different sizes of dummies as shown below [2]

Table 3. Head Injury Criteria values for NHTSA dummy sizes

Dummy type	Large size male	Mid-size male	Small size female	6-Year old child	3-Year old child	1-Year old child
HIC_{15} limit	700				570	390

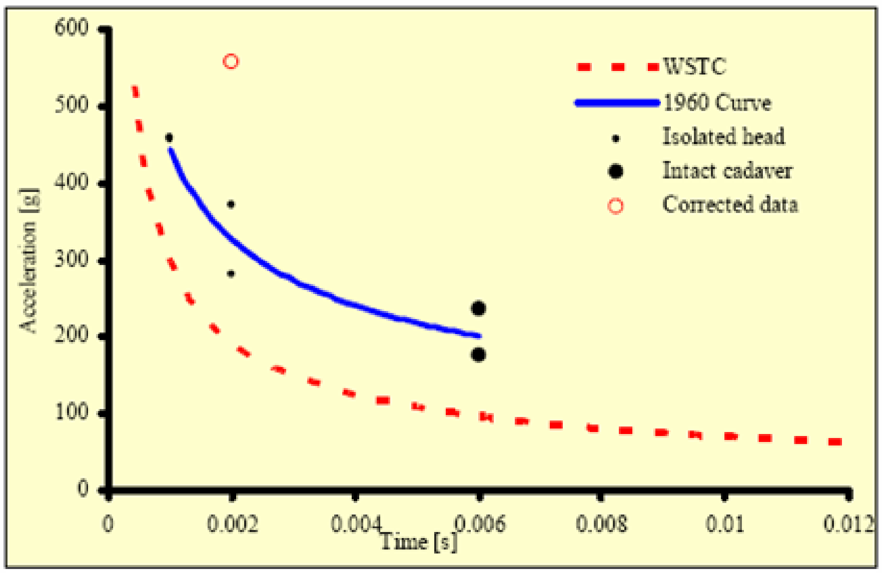

FIG. 4. Acceleration responses from embalmed human cadaver tests and the original and revised tolerance curves [1]

Figure below shows the probability of injury (AIS 4+) as a function of HIC. The head injury risk from real-world data (National Automotive Sampling System, NASS database) at the two speeds falls on the probability curve [1].

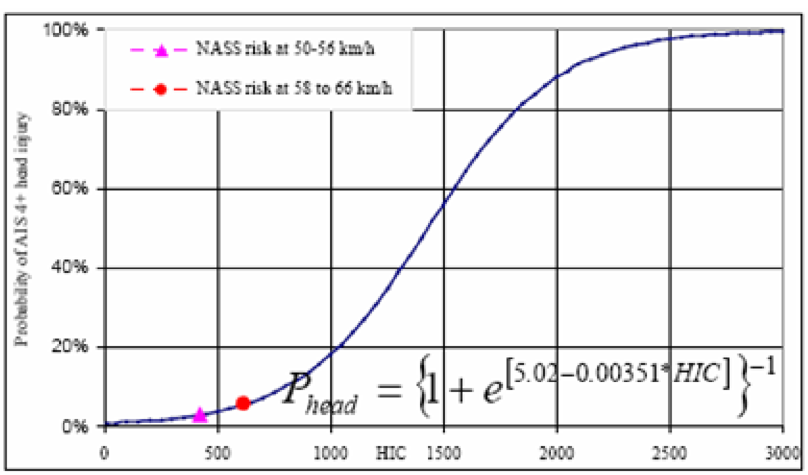

FIG. 5. Probability of head injury as measured by HIC for MAIS ≥ 4 in frontal impacts. Solid circle and triangular symbols show the risk of head injury based on NASS analyses [1]

4. AIS – HIC CORRELATION

On the basis of a lot of post mortal experiments (experiments with dead bodies) [6] a correlation between HIC and AIS has been developed. It should be noted that the following correlation is based on only head-on impact tests [3].

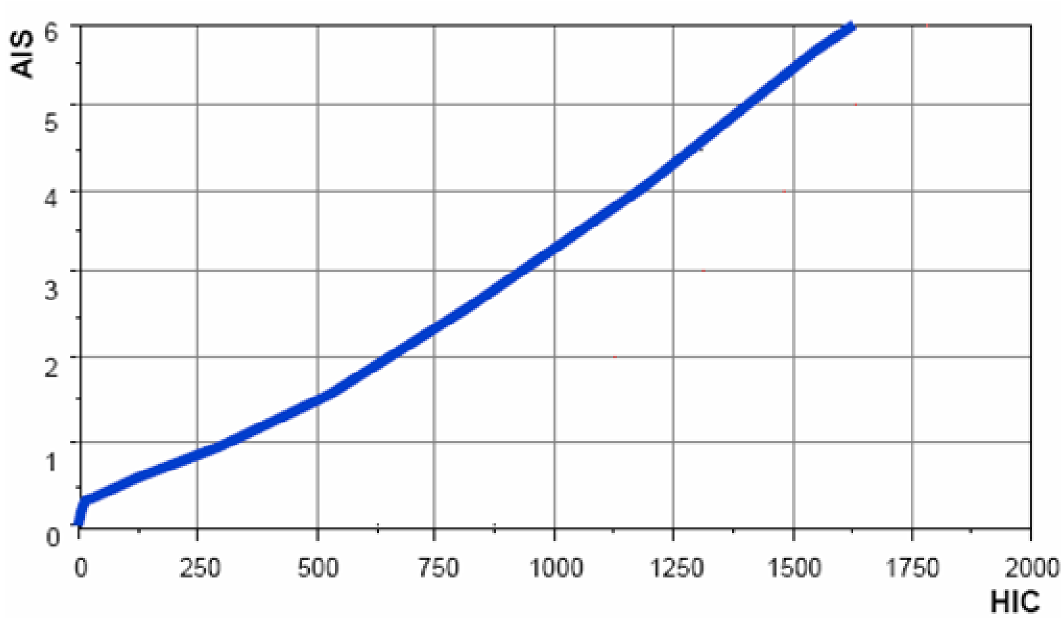

FIG. 6. Correlation between AIS and HIC [3]

5. SIMULATION. TESTING PARAMETERS

PC-Crash 8.0 has been used for simulating the impact behavior and collision mechanics.

Several tests have been conducted in order to determine the influence of vehicle speed for impact mechanics. The resulted acceleration graphs of the multi-body system components simulate for the real human body parts movement.

Parameters:

- initial car speed: 40km/h;
- steering: no steering;
- braking: pedal position: 100%, brake factors: 101.9 on both axles;
- vehicle: one vehicle used;
- pedestrian position: side impact;
- pedestrian parameters: default PC-Crash pedestrian values;
- pedestrian regions analyzed: torso, hip, femur, lower left leg, head, left knee.

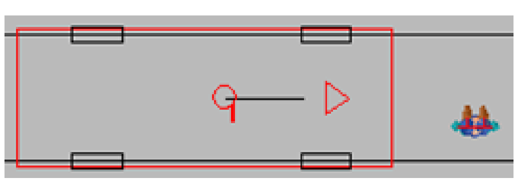

Fig. 7: pedestrian position used

CONCLUSION

The nonlinear increase of AIS severity shown in Tables 1 and 2 and Figures 3 to 5 is clearly supported by the virtual simulation tests.

Also, the simulations show a decrease in lower body parts injuries for a temporary increase in velocity for the particular vehicle tested. The 40km/h impact score the best results for the lower body parts while the head injury clearly increases continuously from start

An impact velocity producing a head acceleration above 60g would develop a HIC_{36} above 1000, which is connected to AIS levels 3+.

REFERENCES

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3. M.Shojaati, Correlation between injury risk and impact severity index ASI, STRC, 2003;
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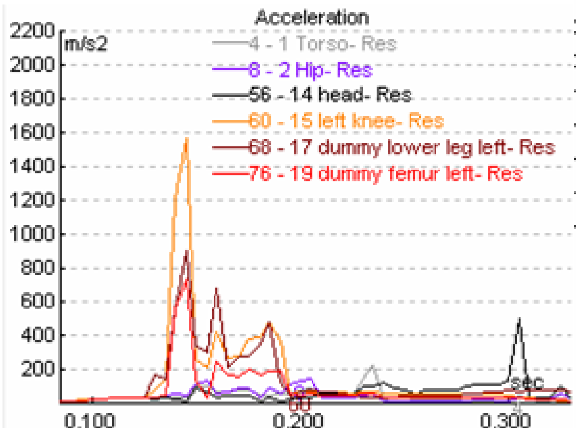
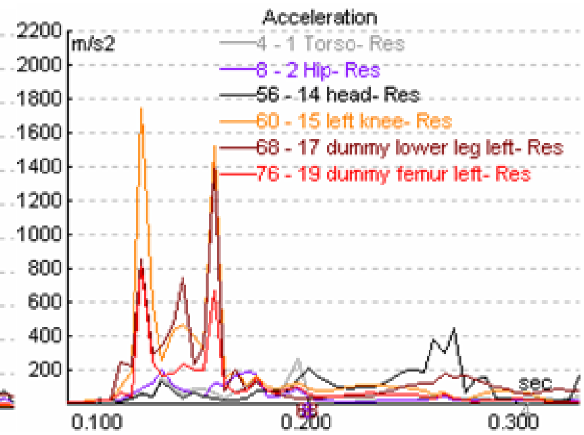
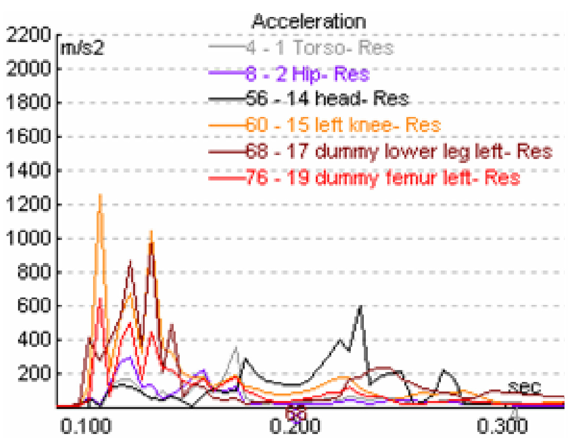
APPENDIX: VIRTUAL TESTING RESULTS



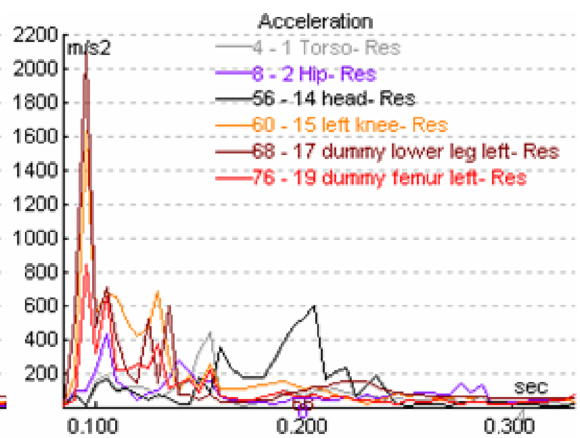
30km/h



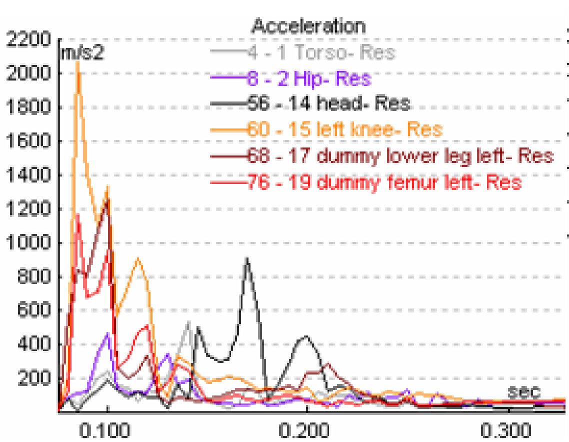
35km/h



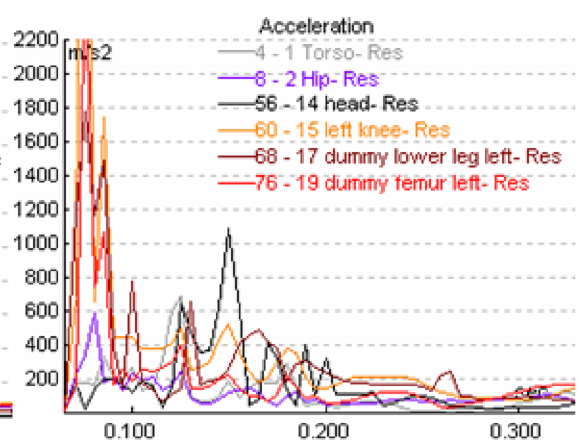
40km/h



45km/h



50km/h



60km/h